Latent Heat of Fusion

Thermodynamics: phase change, latent heat of fusion, melting	

Qty	Equipment and Materials	Part Number
1	PASPORT Xplorer GLX	PS-2002
1	Fast-Response Temperature Probe (included with GLX)	PS-2135
1	Basic Calorimetry Set (1 calorimeter cup)	TD-8557
1	Balance	SE-8723
1 L	Water, about 15 degrees *warmer* than room temperature	
0.5 L	Ice, crushed	
1	Towel	

Purpose

The purpose of this activity is to determine the amount of thermal energy needed to change a specific quantity of ice (one gram) into water at a specific temperature (0º C). This amount of thermal energy is called the Latent Heat of Fusion of water.

Background

Just as steam has a higher internal energy than water, so water has a higher internal energy content than ice. When ice melts into water, it absorbs thermal energy from its surroundings, but does not change temperature. The absorbed energy enables water molecules in the crystalline form of ice to break free of the bonds that hold them together.

The phase change from solid to liquid involves a transfer of thermal energy *into* the substance, but doesn't involve a temperature change for the substance. The thermal energy, ΔQ, depends on the mass, m, and the latent heat of fusion, H_f (the amount of energy per gram needed to change phase at a specific temperature).

$$\Delta Q_{phase\ change} = mH_f$$

If the substance changes from solid to liquid, and then the liquid undergoes a temperature change, the *total* amount of thermal energy involved is the sum of the thermal energy for the phase change and the thermal energy for the temperature change.

$$\Delta Q_{total} = \Delta Q_{phase\ change} + \Delta Q_{temperature\ change} = mH_f + mc\Delta T$$

The thermal energy comes from the environment that surrounds the substance.

Preview

Use a Fast-Response Temperature Probe to measure the change in temperature of a known mass of water as ice changes from solid to liquid in the water. Use the Xplorer GLX to record and display the temperature. Determine the latent heat of fusion of the ice.

Safety Precaution

- Follow all directions for using the equipment.
- Wear protective gear (such as gloves, goggles, and lab coat.)

Procedure

GLX Setup

1. Plug a Fast-Response Temperature Probe into the first temperature port on the left side of the Xplorer GLX and then turn on the GLX (⏻).

- The Graph screen shows Temperature (ºC) and Time (s).

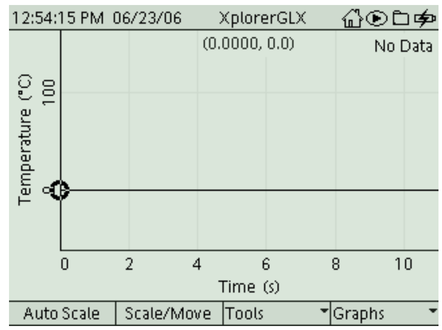

Fig. 1: GLX graph

Equipment Setup

1. Measure and record the mass of a calorimeter from the PASCO Basic Calorimetry Set.
2. Fill the calorimeter approximately half-full of warm water (about 15 ºC above room temperature).
3. Measure and record the mass of the calorimeter plus water.
4. Put the end of the Temperature Probe into the water.
5. Get ready to add chunks of ice to the warm water.

Record Data

1. Press Start (▶) on the GLX to measure the signal from the Temperature Probe.

- The temperature appears in the graph display. Make a note of the initial temperature of the water.

2. Wipe off any excess water on several small chunks of ice and immediately add them to the warm water in the calorimeter. Gently swirl the water in the calorimeter.
3. Carefully watch the temperature in the Graph screen.
4. As the ice melts, dry more chunks and add them to the water, swirling the water continuously.
5. When the water temperature gets as far *below* room temperature as it was initially *above* room temperature, *and* all the ice in the water is melted, stop adding ice.
6. Press ▶ to stop data recording.
7. Remove the Temperature Probe and then immediately measure and record the mass of the calorimeter plus water plus melted ice.
8. Clean up the equipment as instructed.

Analysis

1. Use the graph of temperature versus time to find the initial temperature of the water and the equilibrium temperature, or final temperature, of the water and the melted ice.
2. Press F3 (F3) to open the ‘Tools’ menu. Select ‘Smart Tool’. Use the arrow keys to move the cursor to the part of the graph that shows the initial temperature of the water. Record the value.
3. Repeat the process to find the final temperature (equilibrium temperature) of the water and the melted ice.
4. Use your measurements of the mass of the calorimeter, the calorimeter plus water, and the calorimeter plus water plus ice to determine the mass of the water and the mass of the ice.
5. Use the mass of the water, the mass of the ice, and the initial and final temperatures of the water to calculate the heat of fusion of water.

The ice starts at 0 ºC, melts into water, and then warms up to the same final temperature as the water. The thermal energy transferred *to* the ice as it changed to water and then warmed up is the same as the thermal energy transferred *from* the initially warm water as it cooled down from its initial temperature to the final, cooler temperature.

In other words, the sum of the latent heat of fusion, $\Delta Q_{phase\ change}$ plus the thermal energy for changing the temperature of the melted ice, $\Delta Q_{temperature\ change}$, is the same as the thermal energy for changing the temperature of the warm water.

$$\left(\Delta Q_{phase\ change} + \Delta Q_{temperature\ change}\right)_{ice} = \Delta Q_{water}$$

$$m_{ice}H_f + m_{ice}c_{water}\Delta T_{steam} = m_{water}c_{water}\Delta T_{water}$$

$$m_{ice}H_f + m_{ice}\left(4186 J / kg^\circ C\right)\left(T_{final} - 0^\circ C\right) = m_{water}\left(4186 J / kg^\circ C\right)\left(T_{initial} - T_{final}\right)$$

The first task is to solve for H_f, the latent heat of fusion. Then, substitute values for the mass of the ice, the mass of the water, the initial temperature of the water, and the final temperature of the water.

Record your results and answer the questions in the Lab Report.

Lab Report - Activity 33: Latent Heat of Fusion

Name ________________________________ Date ___________

Data

Sketch your graph of temperature versus time. Include labels and units on the axes. (See Sample Data.)

Data Table

Item	Value
Mass of calorimeter	kg
Mass of calorimeter **plus** water	kg
Mass of water, m_{water}	kg
Mass of calorimeter **plus** water **plus** melted ice	kg
Mass of ice, m_{ice}	kg
Initial Temperature of Water, $T_{initial}$	ºC
Final Temperature of Water, T_{final}	ºC

Calculations

Calculate the mass of the water, m_{water}, where the mass of the water is the mass of the calorimeter **plus** water *minus* the mass of the calorimeter.

Calculate the mass of the ice, m_{ice}, where the mass of the ice is the mass of the calorimeter **plus** water **plus** melted ice (the final mass) *minus* the mass of the calorimeter **plus** water

Use the mass of the water, mass of the ice, specific heat of water (c_{water} is 4186 J/kgºC), initial temperature of the water, and final temperature of the water to calculate the latent heat of fusion.

$$\left(\Delta Q_{phase\ change} + \Delta Q_{temperature\ change}\right)_{ice} = \Delta Q_{water}$$

$$m_{ice}H_f + m_{ice}c_{water}\Delta T_{ice} = m_{water}c_{water}\Delta T_{water}$$

$$m_{ice}H_f + m_{ice}\left(4186J/kg°C\right)\left(T_{final} - 0°C\right) = m_{water}\left(4186J/kg°C\right)\left(T_{initial} - T_{final}\right)$$

First, solve the final equation for H_f, the latent heat of fusion. Next, substitute your values for mass of water, m_{water}, mass of ice, m_{ice}, initial temperature, $T_{initial}$, and final temperature, T_{final}. Finally, calculate the results. The units for the latent heat of fusion are joules per kilogram, or J/kg.

Get the accepted value for the latent heat of fusion for water from your instructor, and calculate the percent difference between your value and the accepted value.

Item	Value
Latent Heat of Fusion, measured	kJ/kg
Latent Heat of Fusion, accepted	kJ/kg
Percent difference	%

$$\%diff = \left|\frac{measured - accepted}{accepted}\right| \times 100\%$$

Questions

1. How does your measured value for the latent heat of fusion compare to the accepted value?

2. What factors do you think may have caused a difference, if any?